Search and Rescue Dog Wearable and Mobile Interface

Yunqi Liu

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Abstract

Search and Rescue (SAR) dogs are important partners in SAR activities since their born talents in olfactory and auditory senses. Traditionally, the SAR dogs are usually released in the last known spot of the target person, doing a range searching, and returning to their handlers if they find any clues. The current process will cause a great waste on time and potential losing in track of the target while dogs returning to handlers. Our research project aims to replace this traditional working mode by developing an interactive computing system to enable a remote communication between the SAR dogs and the handlers. We provide a vest wearable for dog and a mobile application for handlers, and we allow distant data transmission between the vest and a mobile application. Our approach would prevent the returning step, and hence increase the efficiency and effectiveness of the SAR activities. After experiment and alpha test, we prove that our prototype has all desired functionalities with great precision and weight. Further training and testing with actual SAR dogs would be expected and conducted with K9 teams.

Introduction

In most catastrophes, canines play an important role in search and rescue (SAR) activities due to their superior agility, olfactory, and auditory senses. [1] They are trained to deliberately use their born smell navigation mechanism to track and locate missing people, for example searching for and indicating the casualties located under ruins where humans are not able to detect. [1, 2] Nevertheless, the given talent does not work by itself. The current working mode of SAR dogs is called recall-and-re-find which cooperates with handlers who should be equipped with strong navigation skills and understanding of the scent theory, how to best search for people. [3] The SAR dogs are released in the last known spot and do a range searching, and once they find related clues or the targeted people, the dogs will hold the bringsel (a stick attached to the collar) in mouth and run back to the handlers to notify them. [4, 5] However, since the searching usually takes place in large or difficult to access area, if the dog finds the target while being far out of the handler's sight, he must temporarily abandon it and return to notify the handler, repeating this procedure until the handler has reached the target. During this back and forth, the found people may be lost of track again if they move when the SAR dogs return to handlers. As the target is often in danger, the speed and efficiency of SAR activities are essential and hence draw significant attention from researchers.

To facilitate and improve this process, computing technology including camera, GPS trackers, and other sensors have been employed in considerable studies to enable faster and more informative communication between the dogs and handlers. [1, 5, 6] The FIDO lab in Georgia Tech proposed and designed a wearable computer interface prototype consisting of a vest for SAR dogs and an android app for the handlers. In its design, the vest would allowed the dogs to send signals to the app by a capacitive bite sensor, and the app could view the paths which the dogs have travelled, mark the location where the dogs send the signal, and make notes at any point on the map. [5] This conceptual model well demonstrated how to integrate computing technology into the traditional SAR activities. This incorporation idea has received considerable accomplishments for improvement in both the safety of SAR dogs and assistance provided to handler due to real-time monitoring on dog moving state and the map digitalization.

Though this model has shown a promising development trend in the SAR dog computing system and wearable, there are some serious defects which cannot be ignored. Firstly, the FIDO lab current model is mostly a demonstrative prototype instead of a functionable one. Also, it simply embedding a cell phone on the vest serving as the signal tracker and sender, resulting in a heavy weight and large size for some small dogs and short battery life. In addition, the antennas of not only our model but also most other wearables do not perform well in indoor surroundings when there are thick walls. Last but not least, for human handlers, the current app design is not intuitive enough, requiring some tutorials to learn how to use it. And for dogs, the material of the wearable is not very breathable, so that the dogs would easily feel tired during extensive running. [5]

Based on all problems listed above, this research project aims to improve the current design of the system in FIDO lab previous project in 2 main aspects:

1. Replace the cellphone which is currently sealed in the vest to send the GPS coordinates and signals from dogs by a circuit board (also referred as **microcontroller**) which includes the **GPS** and **cellular module**, hence significantly reducing the weight of the wearable and expanding the range of communication.

2. Replace the original hardcoded demonstration mobile app by **developing** an actual **functionable** version of **app**. This process includes development for the frontend and backend of the app and establishment of connection between the app and the wearable.

Literature Review

In the urban environment, search and rescue canines are the most reliable means of finding missing children or searching people in urban disasters. [7] Traditional search and rescue activities are highly manual, requiring dogs to run back and forth to send the feedback when they have any findings. In addition, dog handlers are not able to track the dogs' vitals, behaviors, and working environments, since in some situations, human access is not possible. [8] Therefore developing effective methods and tool to reduce the unnecessary waste in rescue time and unawareness of dogs' situations has been a goal of many rescue teams and scholars for a long time. [1, 5, 8, 9]

As the computing technology fast evolves in both software and hardware during recent decades, canine augmentation technology to monitor dogs' physical conditions and working environment during SAR activities has been invented by various teams through years. Early common attempts include installing wireless camera and microphone in the collar to capture the video and audio feed from dogs, so that information of their environment could be extracted and interpreted from the image and sound captured. [1] One of the earlier innovations of gaining data from canine remotely is the Canine Pose Estimation (CPE) system by Alexander Ferworn et al. [9] The system employed accelerometers for canine pose detection and uses Bluetooth and WiFi for data transmission. In preparation, the team recorded down readings for 5 different poses (standing, lying down, etc.) by observing the angles collected and the correlated canine position. In testing, the system received the measurement via Bluetooth and WiFi to determine the pose of dogs without seeing them. The CPE could successfully detect and distinguish the dogs' body position so that dogs can be trained to indicate different events by making corresponding poses to send back information. [9] The CPE was an innovative way to build up an interaction between SAR dogs and human beings instead of the one-direction, delayed communication between them. However, it had several deficiencies that needed further improvements. First, this design had only limited types of signals allowed to unidirectionally communicate due to a restricted number of poses that the dog can do. Second, the accuracy of readings would be greatly affected by the landscape and other environmental factors and hence may cause misleading interpretation. In addition, the CPE system was not able to track the location of the canines, which was a significant lack of functions especially in finding missing population. Overall, the CPE system is a creative but crude attempt in the canine augmentation technology for the search and rescue area.

As the canine augmentation technologies are gradually explored in studies, the dogs' wearables are equipped with more different types of sensors, GPS tracker, and motors. And all of which units enable more interaction between SAR dogs and the handlers, more informatively and bidirectionally. Bozkurt and the research team in North Carolina State University presented a concept named Cyber-Enhanced Working Dog (CEWD). They developed a dog wearable which held several sensors and WiFi antenna to collect the vital measurements of dogs, send commands to dogs by vibration or sound, and monitor the working environment. [6] To collect the vital signs, the vest installed electrodes including electrocardiogram (for heart rhythm), photoplethysmogram (for blood volumn changes), and thermocouples (for temperature). [6] For monitoring environments, the vest embedded video camera, audio cape, and GPS, and the contents were sent back by WiFi. In addition, handlers can communicate with the dogs by training them with haptic and auditory commands sent by vibration motors and a speaker. The functions of the augmentation equipment were more diverse and helpful in assisting the dog handlers in the search and rescue activities. It provided real-time information of not only the dogs but also the environments they were in, compared with the recorded and later retrieved video taking in the past. Furthermore, the communication also became bidirectional where handlers could send commands instead of just hearing back from the canine. [6] The whole prototype proposed a good model with desirable functions, yet its handler side interface design limited its popularity. Above all, the monitoring program worked on computers which were not convenient to be carried in search and rescue settings. Moreover, the data collected were displayed in a raw, unprocessed form that required extra training in professional data analyzing skills. Beside the defects in feasibility, the wearable did not indicate its water proof capability and wearability for dogs during working. To be of help in real search and rescue activities, the CEWD system should further improve its ease of use and learn.

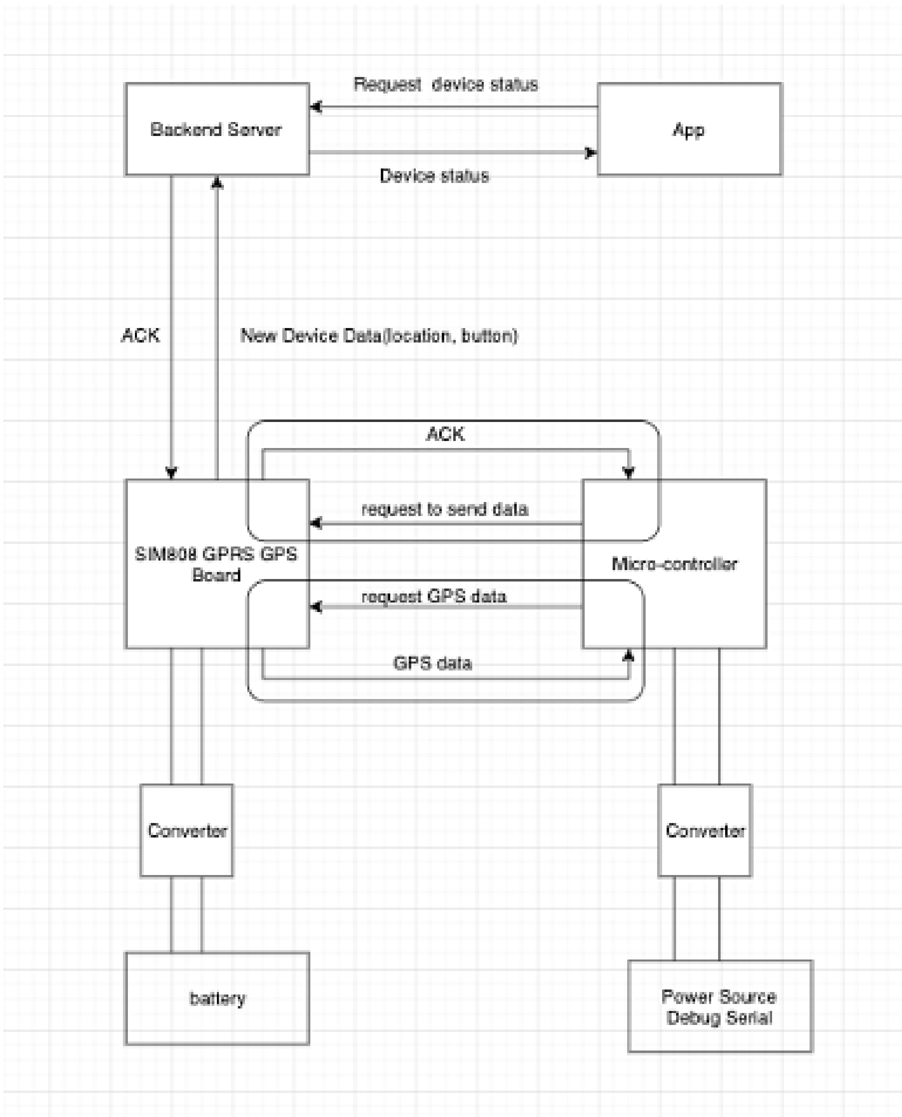
With the user-centered and feasible design in mind, FIDO lab in Georgia Tech has put forward a two-part system composed of a wearable computer interface and an android mobile application targeting searching wilderness. [5] The wearable had components including a Capacitive Bite sensor which will be activated when the SAR dog bites it, a water-resistant cellphone sealed in a water-proof OtterBoxTM to broadcast back the real-time GPS location and the dog bites, and a capacitive sensor chest strap preventing unintentional activation when travelling through water. For the handler side, the mobile application had the Google map as the main view with distinct pins and tracks for handler's current location, SAR dog's current location, trail passed by dog, and locations where the dog activated the sensor. [5] The most deserving feature was that handlers can put notes on a specific point on the map by dropping down a note pin, greatly facilitating them in the SAR process for direct in viewing and easy to trace back. The application was unprecedentedly considerate and user-friendly in design, and support to run on mobile phone makes the whole canine augmentation system more portable, easy to learn and quick for setting up in real use.

However, the system still had space deserved further development. For the wearable side, the cellphone was too heavy and cumbersome for the vest though it has better connectivity compared to WiFi. Besides, more testing on the breathability and heat emission while working were also needed based on the suggestions from expert SAR handlers. [5] For the mobile application, the experts prefer to use the USNG map that was employed in their current training system. They also suggested a voice-text input feature, considering that they may wear gloves during working and get difficult to type in hands. The system proposed by FIDO lab shows a high level of user-centered design even with simpler functions and interaction compared to the previous design, promoting the trend of user-friendly design in order to practically apply the lab prototype to real-world situations.

The current study will improve the prototype created by FIDO lab. Since the system is targeting wilderness searching, it has less inaccessibility for human beings than building collapse or other urban disasters. Thus, the interaction design will remain monodirectional from dog to handler, as in most searching scenarios, the handlers could go to check the locations alerted by the dogs while dogs keep tracing. [5] The data transmission of the new prototype will still use cellular rather than Bluetooth or WiFi to achieve greater communication range, but the cellular technology will be implemented by an independent cellular modem module instead of putting a cellphone on the vest. The GPS location originally obtained by cellphone will be attained by another separate GPS chip module as well. These replacements would significantly reduce the wearable’s size and weight and hence decrease the burden on SAR dogs as sometimes they need to consistently run for over an hour. To improve the software side, an ios version and the voice input function would be implemented, and USNG map would be added as an option for map view. Ideally, this prototype would have higher functionality and ease in setting up especially in wilderness SAR activities, and it would also contribute to arousing awareness of the importance of user interface design.

Methodology

To enable the remote communication between the dog and handler, our prototype consisted of two main parts: a wearable device for the dog and mobile app for the handler. The workflow of the prototype was illustrated by the graph below.



For the device, we replaced the cell phone by the SIM808 GPRS GPS board which integrated a microcontroller section, an antenna, and a battery section. We chose this board because it had all necessary functions that allow us to detect the bite sensor triggering and pass location data back and forth distantly and meanwhile was much lighter and more affordable than a cell phone. For implementation details, we built the power unit that regulates power from the lithium batteries to the GPS and Cellular module, and we also implemented the device program which controlled the using C++ to send real-time location data and bite sensor data to the backend server. In this way, we were able to consistently pass back the to the handler side the freshest data without using too much battery which means less frequency of recharging.

On the software side, we redeveloped an iOS version mobile app from the ground up and implemented the backend server that transferred the data between mobile interface and the wearable. On the backend server side, we used golang and redis to build typical API as the endpoints to serve/push the device data and persist the data in the server. For frontend, the iOS app was in iOS 8, and the supported Google API version was 2.7.0. The selection of version was for downward compatibility consideration. We established the connection and data transmission between frontend and backend through http request and json data passing. To display all the data received, we designed the main panel by using Google Map API which could straightforwardly show data related to the geographic information.

The map interface was able to show the real-time location of the handler and the dog as different color dots on the same map view without need to switch between different pages. And we designed 2 “located” buttons which allowed users to switch the view camera center to either the current location of the dog or handler by tapping these buttons. The buttons utilized dog and human images as customized icons, providing more intuitive visual guides for users. In addition to customized center view, we enabled the compass feature and the current facing direction for both dogs and handlers to have a better sense of direction in SAR activities. And by consistently tracking the real-time location of the dog, we plotted the path the dog has walked on the map, so that the handlers would have a mind about what scope has been searched. Once the dog triggered the bite sensor, the app would instantly receive the json data package from the backend and drop an exclamation mark pin on the location where the alert was sent. The pin contained information of time, latitude, and longitude of the alert. Another core feature implemented was that the handler could long press at any spot on the map, and an input box would pop up for note taking, and finally a customized note pin would be dropped on that location. This map digitalization allowed the handler to make notes at any place on the map like holding a paper map but in a more quickly retrievable way. The handler could tap the pin, view the notes, and tap out to dismiss the notes at any time without making the map messy. Last but not least, in order to make least effort for users to get hands on the app, we implemented the most basic set of gestures on the map view which were similar to manipulating the Google Map, including double-tapping (zoom-in), single-tapping (select) and dragging up/down (zoom out/in), etc.

Evaluation

Evaluation Plan

<u>Focus of the Evaluation:</u>

Our evaluation metrics designed based on the new functionalities test, the conveniency of using, the sustainability, and the safety requirements for dogs required by K9 experts in previous interview when designing the old demonstrative model.

- Functionality:

  1. Does the wearable meet the safety standard for dog-use?
  2. Does the wearable perform all designated functions?
  3. Does the wearable have a stable performance?
  4. How is the wearable reusability and lifetime?
  5. Does the app perform all designated functions?
  6. Does the app have a stable performance?

- Design:

  1. Do the professionals feel current functionalities useful/useless?
  2. How is the wearable in weight, breathability, convenience?
  3. Is the app interface user-friendly and self-intuitive?
  4. Is any instruction about using the wearable and app needed?

- Potential Development:

  1. What are the defects in the current design that need to be solved?
  2. What are some desired functions that could be developed in the future?

Evaluation Process:

- Methods:

  To test the performance of the complete kit, I think we should do a search and rescue activity mock with K9 dogs and professionals. Before the mock, we should train the participant dog about the mechanism of the wearable kit. We would observe if the SAR dogs can learn how to run signals without running back, and what would be a terminating signal for them that tells them the activity is completed. During the mock, we should observe the professionals' user behaviors with the app and if they approach every function as what we think. To observe if our wearable computer interface improves the efficiency, another SAR activity mock with similar level of difficulty should be conducted in the traditional ways, and the time usage would be measured and compared. After the mock activity, we would interview with the professionals about their user experience, opinions about the wearable and app, and functions they want or dislike.

- Consideration Factors:

  1. How large would the range be for the mock SAR activities? How many meters/miles?

  2. How many dogs should we test with? What size should the dog be?

  3. How to keep each SAR mock activity at a similar difficulty level in order to compare?

Evaluation Questions and Indicators:

The following are questions required to be answered by this evaluation. We would use the below indicators to check the evaluation effectiveness.

What do we wish to know	**Indicators – How will we know it?**
Does the wearable send real-time dog location?	Let the dog move in a sighted area and print the location of the dog on the server monitor. See if the location changes received on the server reflects the dog real location changes.
Does the wearable successfully send the alert signal when the dog bite the sensor?	Let the dog bite the sensor in a sighted area and print the signal in the server monitor. See if we receive the signal when the dog bite, and how long the delay would be.
Does the wearable have stable network connectivity?	Observe if there is any error or disconnection occurred during the device running.
Does the wearable meet the safety standard for dog-use?	Check with FIDO members and the professionals about the material safeties.
Is the vest light and convenient enough for dog to wear and avoid possible trapping in bushes?	Interview with FIDO members and the professionals. Observe the dog's adoption of the vest during SAR mock activity.
Is the wearable waterproof?	Test beforehand with tissue putting in the waterproof box instead of the real device.

	Imitate potential dragging, pulling, pressing on the box to see if water would leak in.
How long would the battery last, and is it rechargeable?	Do an estimate on the battery life first, and then hand test if the battery can sustain 5 hours or more.
Is the app able to track the real-time location of the handler?	If the device is working fine (sending the correct signal to the server monitor), then see if the app shows the correct location of handlers by walking around.
Is the app able to track the real-time location of the dog?	Let the dog move in a sighted area and see if the location of the dog on the app map changes correspondingly.
Is the app able to receive and show the alert from the dog?	Let the dog bite the sensor in a sighted area and see if the alert pin shows up on the map.
Is the app able to show the path of the dog?	Let the dog move in a sighted area and see if the path of the dog is plotted correctly on the app map.

Is the app able to drop note pins at any location on the map?	Let the professionals test if they can long press the screen, input their notes, and drop on the map at any location and any time during the SAR mock activity.
Is the app interface user-friendly and self-intuitive? What is the minimum level of instruction needed?	Let the professionals approach the app by themselves firstly. See if they can understand what functions are available and how to use them. If the professionals are missing any functions or getting stuck at some point, we would try to give the minimum amount of instruction to assist their understanding. In the interview, we would ask what level of instruction they think would be helpful.
Is there improvement in SAR efficiency by using our prototype?	Conduct a SAR activity mock in a traditional search way with a similar level of difficulty with the one using prototype, trying to control all variables but the difference in methods. Measure the time use of two methods and compare them.

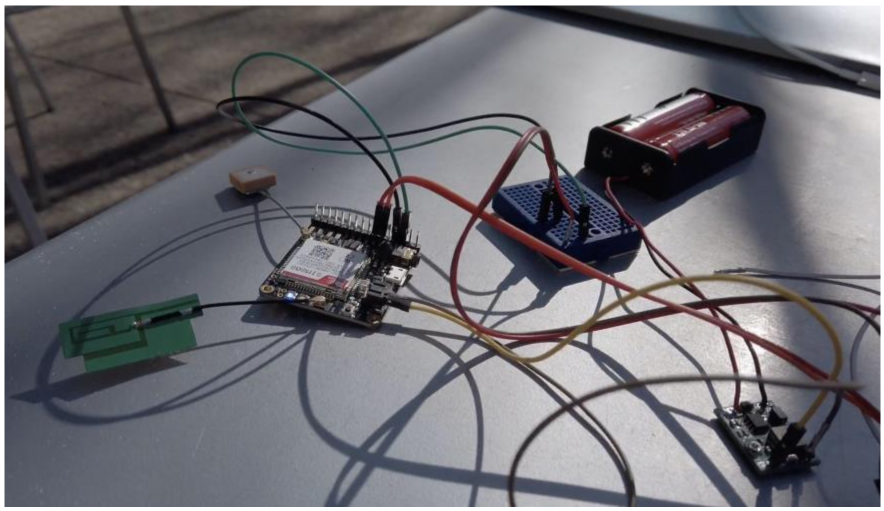
Do the professionals dislike any functions?	Interview with the professionals about their opinions on our prototype design. What are the functions that they feel not necessary? What are the functions not well implemented?
What functions do they want but do not have for now?	Interview with the professionals about their opinions on our prototype design. What are the functions important but missing?

Results Sharing**:**

We hope that the SAR activity mock could be video recorded, and the interview with professionals could be sound and text recorded. Rights of video and sound recording would be requested from the professionals. After the test, an evaluation report will be drafted to answer all questions listed out above and to reflect on our prototype and evaluation plan.

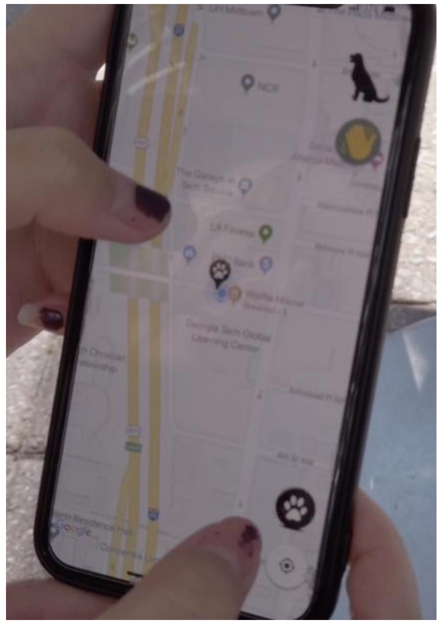
Experimental Results

We did alpha testing for the fundamental functionalities except for the bite sensor. We used a button trigger functioning as a bite sensor in this initial experiment. Below is the picture of the hardware component which includes the main controller chip with all modules embedded, the antenna, the battery, and the button trigger.



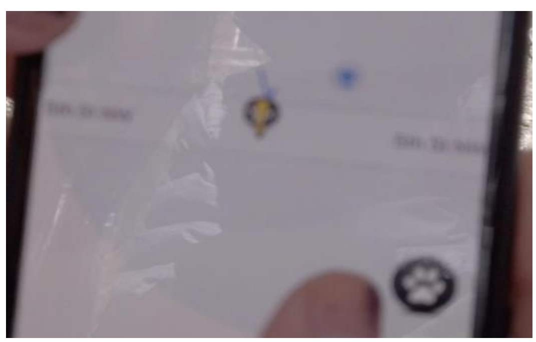
(Hardware)

In the testing, we were able to track the real-time location of both the dog and the handler on the map. The black pin with paw sign showed the location of the dog, and the blue dot showed the location of the handler. The map could be centered based on either the dog or the handler by the buttons on the lower right corners.



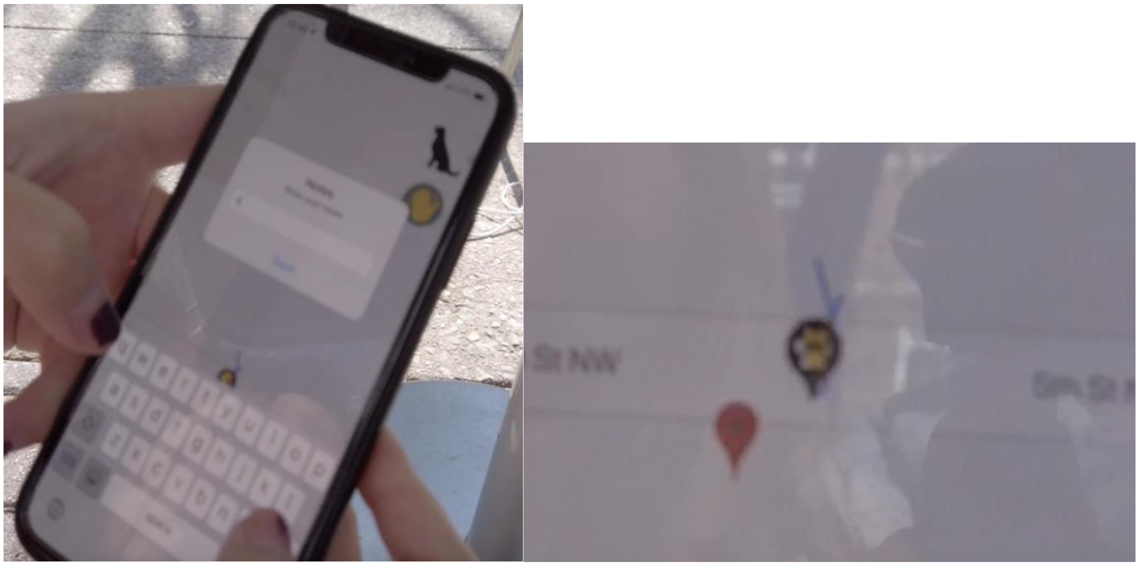
(Real-time location)

We also successfully tested out the alert function from the dog. Once the button trigger was pressed, a yellow exclamation mark was dropped on the map at the location where the dog sent out the alert. By clicking the exclamation mark, we could see the longitude and latitude of that location.



(alert signal)

The note taking function was also tested as the graph below. By long pressing any point on the map, an input box would pop up to enter any text. When input was done, a red note pin was dropped on the press point, containing the input text and geological information.



(note input and pin)

Finally, all desired functionalities were successful in our alpha testing. In addition, we also noticed that the precision range of the dog and the handler’s location was within 10 meters radius of the real-time location. This precision was quite ideal since the search range was normally in scale of miles, and the searching target (people) was usually large enough to be viewed in 10 meters.

Conclusion and Future Scope

In conclusion, we have provided a functional computing interface to replace the traditional recall-and-refind process. The interface well establishes a distant communication through the wearable and user-friendly mobile application to save the communication time while remains accurate and precise on geographic information. As all the above performance were proved in the alpha testing, we would further conduct the evaluation with the Atlanta K9 team and do an interview for feedback. The testing of the next stage would mainly focus on whether the dogs and their handler could effectively and comfortably utilize this tool. We would further improve based on the feedback about the user experience and professional advice about the wearable safety and comfort for dogs.

Besides, there are also some features which we are considering extending on the current model. The first one is to allow tracking for multiple dogs on the same map since there are usually more than one dog involved in a single SAR activity. Secondly, bidirectional communication through sound could be established. Some voice commands could be sent out through the currently unused speaker module, such as “sit” or “come back”, so that the dog could get more useful instructions from their handlers remotely rather than unidirectionally sending information to handlers. Furthermore, more sensors could be added to the device to monitor the status of the SAR dogs in order to guarantee their safety, for example temperature, hazardous gas.

Through this project, we strive to underscores the importance of computing technology integration which allows us to have more efficient and remote communication in the SAR activities. Following and proposing this trend, we would continue on improving the traditional recall-and-refind behavior model considering the time saving, information electonizing, and convenience.

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